## Art. XI.—*Volcanic Necks at Anderson's Inlet, South Gippsland, Victoria.*

By A. E. KITSON, F.G.S.

(With Plates XVIII., XIX.).

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In his valuable Report on the Geology and Mineral Resources of South Gippsland,[1] Mr. R. A. F. Murray, late Government Geologist, thus briefly describes an occurrence of volcanic rock, and illustrates it by a section and ground plan :—"Fig. 7 illustrates the section at Townsend Bluff, with an apparent lava pipe, which occurs in a circular form, about 20 yards in diameter."

Having for a long time desired to see the occurrence, it was not until recently that an opportunity was afforded to do so. A close examination then disclosed the fact that a most interesting geological occurrence was here visible. Its intimate connection with, though considerable diversity from, volcanic occurrences in the adjoining district makes it necessary to allude briefly to the latter. Before doing so, however, it will be advisable to make a few remarks on the general geology of the district.

From the accompanying map of the geology of this portion of South Gippsland, which map is based on the new geological map of Victoria, compiled by Mr. Arthur Everett, it will be seen that between the Tarwin and the Bass Rivers, the country may be divided physically into two general divisions, and geologically into four.

### Physiography.

*Division 1.*—Between the Bass and the Powlett Rivers the country consists of rugged hills reaching an altitude of over 1000 feet near Korumburra. They are much broken by faults and landslips, and form steep escarpments along the valleys of the two rivers. Numerous small streams run through it, the tributaries of the Bass having a general westerly course, while those of the Powlett run in a southerly direction.

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1 Prog. Rep. Geol Sur. Vic., pp. 143, 144.

*Division 2.*—Between the source of the Powlett and the Tarwin Rivers the country consists of undulating plains, rising to the height of over 300 feet above sea level near Leongatha, and extending to the Southern Ocean and Anderson's Inlet, either gradually, as along the valleys of Pound, Screw and Wreck Creeks; or terminating abruptly in cliffs up to 100 feet high, as along the coast from Wreck Creek to west of Cape Paterson.

## Geology.

*Division 1.*—The country between the Bass and the Powlett Rivers, with the exception of a small area to be mentioned later, consists almost wholly of felspathic, argillaceous, calcareous and carbonaceous sandstones, shales and mudstones of the Jurassic[1] system. They contain numerous seams of good black coal. These seams are chiefly thin ones, varying from less than one inch to six feet. Within this area are situated the Victorian Coal Fields of Outtrim, Jumbunna and Korumburra.

Dispersed throughout the district, particularly in the basin of the Foster, are numerous localised volcanic occurrences, comprising plugs and dykes of dolerite and basalt, with apophyses therefrom, representing the necks of old volcanoes. They vary in extent from the largest reaching a surface area of about 30 acres, to the smallest, occupying but 3 square feet. The exception previously referred to is an area of about 250 acres at Kongwak on the Foster, where an inlier of Silurian occurs.

*Division 2.*—The country between the Upper Powlett, the western tributaries of the Tarwin, and the Tarwin itself is diverse in character.

Around Leongatha and north of Ruby it is mainly of volcanic origin, comprising laterite, flow basalts and tuffs. There are, however, strips of pebbly gravels, and these, and the volcanics rest on Jurassic sandstones near Ruby. These gravels belong to the Cainozoic system.

*Division 3.*—Between the Middle Powlett (that part of the valley south of Outtrim), Anderson's Inlet, and the Lower Tarwin

1 These strata were formerly referred to by the Geological Survey of Victoria as Jurassic, and later on as Trias—Jura. A reversion to the former name has, however, now been made.

there is a wide stretch of country constituting the Powlett and Tarwin Plains, covered in the main with pebbly drift, gravels and sands, with a few isolated patches of laterite tuffs and plugs of basalt.

*Division 4.*—Between the Middle and Lower Powlett and the coast there is a varying, though thin, capping of sediments, chiefly clays, and sands of æolian origin covering the Powlett Plains.

The greater portion of the coast line itself is composed of Jurassic strata forming bold cliffs. This series extends to the hill country, underlying the thin covering of Cainozoic sediments over the greater part of the area. Jurassic rocks are visible at the surface for some little distance inland from the coast between Wreck Creek and Cape Paterson; while between Cape Paterson and West's Creek there are two inliers of Silurian strata, discovered by Mr. W. H. Ferguson, during the progress of his survey of the Cape Paterson Quarter-sheet.

During the progress of my survey of the Jumbunna Quarter-sheet, extending from the Powlett Valley to Korumburra, numerous small and large volcanic plugs and stumps of old volcanoes were found, as has already been mentioned. They have been intruded into or thrust through the carbonaceous strata of the Jurassic system. They comprise three general types of rock:—

(*a*) A coarsely crystalline rock, probably dolerite, comprising the largest neck, and several smaller ones.

(*b*) A dense olivine basalt with large included crystals of hornblende, biotite and felspar scattered through it, besides fragments and blocks of the invaded strata, and usually occurring as small and medium plugs.

(*c*) A dense or finely crystalline basalt as a rule, with or without amygdules of calcite, and small patches of olivine. This occurs as small plugs and dykes.

An occurrence similar to these was, therefore, expected at Townsend Bluff, but examination revealed a neck of different character. Though containing a considerable amount of basalt it consists for the greater part of clastic volcanic material such as agglomerate, tuff, lapilli, and what appears to be volcanic mud with included blocks and fragments of the adjacent Jurassic strata, and decomposed basalt of different character to that of the basalt in mass.

I was also informed by Mr. A. Cuttriss, a resident of the locality, that basalt occurred in two places in the cliffs further to the east. The locality indicated was subsequently examined, and furnished three additional examples of necks, one of them of much greater size than that of Townsend Bluff. For the most part these occupy an area beyond tidal influence, so that their characters are not nearly so well shown as in the smallest, but splendid example to the west. They, however, possess features distinct from this one, and will be described in detail in their turn.

For the sake of convenience the necks will be referred to by numbers, commencing with that at Townsend Bluff.

## Volcanic Neck, 1.

This neck is located at Townsend Bluff, at the mouth of Screw Creek, on the beach opposite allotment 2, parish of Drumdlemara. It occurs among Jurassic sandstones, shales and mudstones, planed down fairly level, and exposed at low tide. It has a roughly circular shape with irregularities, the greatest one forming a pronounced bulge in the south eastern portion. Its diameter in this direction, as far as visible, is about 25 yards, while a north and south diameter is about 21 yards. Nearly the whole of the periphery is visible.

For a considerable portion of its periphery, especially on the north, west and south there is a narrow shell—if it may be so called—of a finely vesicular scoriaceous basalt, or mud basalt. This has a laminated appearance, the jointing being vertical, or parallel with the wall of the neck. This shell stands up above the general level of the neck, owing to its greater resistance to decomposition and wave action. Owing to its jointed character it is impossible to obtain a museum specimen, and it weathers into a ragged surface. This shell is only a few inches thick, but similar material, though quite decomposed, and still exhibiting its laminated appearance extends for some few feet into the neck. There are, however, several isolated patches of the hard rock in the body of the neck, the largest one occupying the visible south-eastern portion of the neck. Whether or not it extends to the margin of the neck could not be determined, as sand, mud and sea-weed obscure the surface.

The main portion of the neck consists of agglomerate, formed of a heterogeneous mixture of blocks and fragments of decomposed basalt, different in character from that present in a hard state; Jurassic strata, such as sandstones, shales and mudstones; tuff, lapilli, and a material that looks like a volcanic mud. The included fragments of Jurassic strata are in some cases considerably indurated, but generally show little evidence of alteration. In the northern portion this material is of finer texture, and shows rude prismatic and spheroidal structure. Along the southern edge for several yards in two separate streaks, lying between the laminated basalt and the containing sandstones, there occurs vertically laminated tuff, varying from a quarter of an inch to 9 inches in thickness. The included blocks of Jurassic sandstones, mudstones and shales range in size up to 6 feet by 4 feet, those of decomposed basalt being much smaller.

The northern portion of the neck runs out into a sharp point where the contiguous fine argillaceous sandstone shows distinct curved structure on a small scale, the jointing being about vertical, and following the curve of the adjacent part of the periphery.

The sandstone is slightly hardened, but otherwise not altered.

The Jurassics here form portion of a dome which extends along the beach in a north-easterly direction. The neck has been formed in the north-western portion of this dome. The contiguous strata dip generally N.W. at about 28 deg. on the north-western edge, and curve a little to the N. along the northern edge. Numerous faults may be seen, but their characteristics cannot be definitely ascertained owing to the overlying sand, mud and water. They will be briefly described under a separate head.

### Volcanic Neck, 2.

This neck is a much larger one than Neck 1, in fact it is the largest of the group. In character it differs greatly from Neck 1. Almost its whole visible portion consists of an agglomerate.

It has a visible length from north to south of about 12 chains, and a visible breadth of about 8 chains. It appears both at and below high-water mark, and in the cliff, where it forms a distinct swelling in the coast-line. Below high-water mark it can be seen fairly well in some places, though the greater portion within tidal influence is covered with sand and mud. It disappears beneath the northern channel of Anderson's Inlet with a breadth of some six chains, and probably continues in a south-south-easterly direction for several chains more. Neither its eastern nor its western margin can be seen, owing to mud and sand, but the occurrence of basalt and agglomerate three chains to the east of the visible margin probably proves that it extends easterly for that distance.

Jurassic sandstones, however, which outcrop close to this spot, clearly limit its further extension in that direction. On the western side no rock is visible among the mangrove-covered mud and the sand of the channel west of a southerly line along the visible western margin.

In the cliffs the eastern and western margins are both marked by small gullies. On the opposite side of each of these gullies the grey soil from the Jurassics affords a clear distinction from the black soil of the volcanics.

The form of this neck as seen is, therefore, roughly that of a truncated ellipse. By far the greater visible portion of it consists of agglomerate, the main mass of which is composed of coarser fragments than that of Neck 1. It contains fair-sized lumps of hard dense fine-grained, highly-spheroidal basalt, with patches of green olivine. In the cliff the agglomerate can be seen in undecomposed blocks constituting a very hard rock. On the beach, where, subject to the action of salt water, it is, as a rule, quite decomposed, when the contained fragments can be easily separated from the matrix. Some of the agglomerate, again, is an intimate mixture of dark dense basalt in small fragments, calcite, and an amorphous or crypto-crystalline, pasty-looking material. It weathers with a brown surface, on which the fragments of basalt show as dark blotches.

There are several kinds of basalt distributed through the mass. One found near the foot of the cliff is a very dense dark basalt of medium texture and high specific gravity. It contains a good deal of calcite, which occurs in amygdules, as films along joint planes, and in patches merging into the basalt. It decomposes with a reddish-brown surface, but forms a fairly dark soil. A fair-sized patch of similar rock occurs on the beach under high-water mark. It wears into ragged edges.

A very vesicular basalt, of fine texture and brownish-grey colour, occurs as a block among agglomerate in the cliff. The vesicles are apparently caused by the decomposition and removal of the carbonate of lime from amygdules of calcite. There is also a little lapillaceous tuff, consisting for the most part of fragments the size of peas, and showing distinct bedding. It has a considerable amount of greenish-grey volcanic mud, and blunted pieces of the fine decomposed basalt up to the size of pigeons' eggs. A pretty rock of light drab-grey colour, grading to yellow at the surface, a decomposed basalt, occurs as an inclusion in dense basalt on the beach, west of the private jetty built by Mr. Cuttriss. It is composed of multitudes of thin, narrow, transparent, colourless crystals up to one-sixteenth of an inch in length, set in a matrix of yellowish clay, probably decomposed felspar. Another kind of decomposed basalt of light grey and yellow colours occurs at this spot. It is an intimate mixture of minute crystals with occasional vesicles of clay. It resembles very much the included pieces of decomposed basalt in the agglomerate of Neck 1.

There are two other rocks found in this dense basalt which are of interest. One is of dense, hard, dark blue amorphous material with small amygdules of yellowish-brown ferruginous powder. It is a rock with a peculiar appearance, and gives one the impression of being a form of a mud lava or basaltic mud. It also contains small patches of olivine, partially altered about the edges into an opaque white substance. Small lenticles of this hard amorphous material also occur in parts of the agglomerate in the cliff, and they would probably be turned by decomposition into the brownish-grey mud comprising the lenticles in the decomposed agglomerate on the beach.

The other rock is a light and medium grey compact mud, with numerous very small amygdules of a brown glassy mineral. The rock weathers a light grey, and is a good deal like the last mentioned. They both appear to have been formed from the solidification of pasty material of basaltic origin, perhaps crushed or ground-up basalt mixed with liquids, and to have gained their olivine crystals from this rock, or picked them up as fragments during movement in the neck.

*Included Pebbles.*

The special feature of interest in this agglomerate is, however, the presence of numerous small and medium-sized pebbles and fragments of pebbles. These occur in some places in considerable numbers, and may be seen either lying loose on the surface of the disintegrated material, or embedded in the matrix. The pebbles range from the size of mere gravel to that of a goose's egg. In fact, one large pebble of quartzite was found on the mud-covered surface east of the jetty, but within the boundary of the neck. This pebble weighs several pounds, and is 8 inches long by $5\frac{1}{2}$ inches broad and $3\frac{1}{2}$ inches thick. Judging by its appearance when found, and its location, it had apparently been disintegrated from the subjacent material. These pebbles occur chiefly towards the southern end of the neck, west of the jetty, but they probably also occur between here and the foot of the cliff. Drift and blown sand, however, covered with tea-tree, hide the surface of the neck from sight. A few pebbles are also obtainable from the soil in the cliffs.

Comparatively few of them occur entire. Most of them have been transversely fractured, or have lost chips. Their general shape is a flattened oval; some are cylindrical; others rounded and flattened, oval truncated, flat, quadrangular and semi-rounded and irregularly shaped with flattened sides. A few show rude facetting. They comprise the following rocks, as well as can be determined roughly, viz: olive mudstone; red, brown, yellow, dark black, blue and reddish-brown plain and banded jaspers, odd ones showing thin streaks of white silica; greenish-grey and bluish-grey slightly pitted rocks like hornstone; yellowish-white quartz schist; fine to coarse yellowish-white, bluish-grey, brownish-grey and white sandstones, some with thin quartz veins; white, yellow and rose quartz of various kinds, transparent and opaque, semi-opaline, chalcedonic, and opaque-white, with thin transparent veins of silica; plain and banded quartzites of grey, brown, bluish-grey, black, and reddish-grey colours, and a blue variety showing a network of white veins; altered quartz—

conglomerate of grey colour; grey, greenish-brown, yellow, bluish-grey, white, grey and black plain cherts, and black, grey, white, brown and dark-blue mottled cherts; a grey-coloured rock like quartz felsite; white and pale yellow chalcedony, with very pitted ragged edges; carnelian; chalcedonic breccia; brown spherulitic rock like quartz-felspar-felsite; silicified wood; and an igneous rock that looks like a very dense basalt or melaphyre. It is a crystalline rock with felspar and small green crystals like olivine, and is of medium grey colour.

Some of the cherts have a fragmental appearance, and they all are extremely like the rock of some of the pebbles of the Cainozoic gravels of the Powlett and Tarwin Plains. They have undoubtedly been derived from the same source, or from similar rock masses.

The silicified wood has the same general appearance as much of that found among Jurassic strata in the State. A microscopical examination is, however, necessary before a conclusion can be arrived at as to its Jurassic age. Certainly the Silurian or older strata did not furnish it, and there is no evidence of the occurrence of any younger Palaeozoic strata anywhere near this district, even if plants of the nature represented by the wood flourished during those periods. The silicified wood may, nevertheless, belong to the Carboniferous or Devonian period, and have been transported in a silicified state by driftwood, floating ice or floating islets far from its home. The occurrence of large blocks and small trees lying prone among fine and coarse sandstones, and including among the roots of the trees a bluish or olive mudstone quite distinct from the containing strata, clearly indicates their driftal origin.

Should, however, this silicified wood be determined as Jurassic, it proves that silicification of some at least of the carbonaceous material in the Jurassic strata was carried out during the Jurassic period.

## Volcanic Neck, 3.

This neck lies to the north-east of Neck 2, and about 6 chains distant from its northern end. Jurassic strata occupy the intervening area, as evidenced by the soil, and pieces of rock in water channels.

The visible portion has a length of about 3½ chains, with a breadth of about 1½ chains, the whole of it as seen being in the cliff and slope of the hill. It has a general south-easterly bearing, and probably extends for some distance out into the flat, but as the flat is here covered with drift and blown sand, nothing beneath is visible. Even in the cliff the nature of the material constituting the neck cannot be clearly determined.

As far as can be seen the neck consists of a plug of dense, hard, dark blue basalt, forming a low swelling on the top of the cliff, and extending in a south-easterly direction down to the flat. As it approaches the flat it narrows very much, and appears to be only a few feet wide at the foot. This basalt apparently forms the eastern margin of the neck. On the western side of the neck there is a considerable quantity of tuff, containing a few pebbles similar to those in Neck 2. Those obtained vary from the size of a small marble to that of a pigeon's egg. There are, also, visible on the surface, pieces of agglomerate and fine and medium-grained decomposed basalt, similar to that in Necks 1 and 2. There are, besides, pieces of what looks like volcanic mud—an amorphous or crypto-crystalline, soft, compact material of dark grey colour. It resembles, somewhat, the small lenticles referred to in one of the basalts of Neck 2, and also that obtained from another volcanic occurrence, probably a neck, situated in allotment 97, parish of Leongatha, to the north-east.

### Volcanic Neck, 4.

Separated from Neck 3 by Jurassic strata, and distant from it 5 chains to the east lies Neck 4. Its western margin is clearly defined by a small gully, but on the eastern side there is nothing definite to aid one in fixing its margin. The visible portion of this neck also occurs in the cliff, but probably extends in a southerly direction into the flat, where, however, sand obscures the view. As far as can be seen, it is oval in shape, its length in an east and west direction being about 6 chains, and breadth 2 chains.

It, again, differs from the preceding necks, inasmuch as it is almost wholly composed of a homogeneous grey tuff containing grains of sand and a few pebbles similar to those in Necks 2 and

3, but much smaller than the average size of them. Towards its eastern margin there is a dyke or plug of basalt having a width of about 6 feet in the cliff, and a N.W. and S.E. bearing. In the flat to the south-east two drains reveal a dyke of basalt 10 inches wide, having the same general bearing as that in the cliff. Probably it is the southerly extension of that dyke. This basalt is a hard, dark blue, dense rock, much like that in the plug in Neck 3, and it contains amygdules of calcite and patches of green olivine. It weathers a grey colour like that of the soil from the Jurassics, and can be traced up the cliff for some 2½ chains. The latter part of its course is through Jurassic strata, the former through tuff. It is probably somewhat younger than the tuffs of the neck, though practically contemporaneous with them.

Packed up against the foot of the cliff, here about 30 feet high, are blocks of a dense, hard, coarse olivine basalt, and a few loose pieces of agglomerate thrown out of drains on the flat. The olivine occurs in patches over 1 inch in diameter. It is, therefore, probable that the neck extends for some little distance into the flat, where it may partake more of the character of Neck 2.

The tuff of this neck differs from the ordinary tuffs of the district. It has more of the character of a friable, granular, rather incoherent clay, and contains numerous grains of quartz sand. It induces the belief that it consists of a mixture of sedimentary and volcanic material, and this it probably is. The absence of a greater proportion of sand grains may be explained by supposing most of the visible material to be a mixture of Jurassic mudstone in a pulverised state, with volcanic dust or fine tuff.

## Other Local Volcanic Occurrences.

In addition to the basalt showing within the boundaries of the volcanic necks, there are several other occurrences of this rock among the Jurassic strata. Three of these occur close together, between 6 and 8 chains north-east from the northern end of the jetty. The most easterly one is a dyke of basalt, 6 inches wide and about 20 yards long, having a N.E. bearing. The rock is a dense black basalt of fine texture.

The most westerly one is a narrow dyke 1 foot wide and 15 feet long, bearing 312 deg. The rock is a dark blue rock of medium texture.

The middle, and much the largest, one has the shape of a lenticle truncated at both ends. It has a bearing of north and south, with a length of about 15 yards, and breadth at north end of 4 yards, and at south end of 4 feet. It is composed of a highly spheroidal, slightly vesicular, rock. This is highly decomposed, and differs in character from the basalt of the necks. It appears to be more of a mud basalt, and peels off into thin shells.

The last local occurrence of basalt to record is what appears to be a dyke branching from Neck 4, either from the dyke on its eastern margin, or from some larger body of basalt in the flat, hidden from view by sand. Small blocks of it can be seen at the foot of the cliff on the eastern boundary of allotment 3, parish of Drumdlemara, within which allotment are also embraced Necks 3 and 4, and portion of Neck 2. This dyke can be traced for at least 2½ chains west from the boundary, and also for some distance to the east. It has a general bearing nearly east and west.

## Adjacent District Volcanic Occurrences.

Before leaving the consideration of the necks, it is advisable to mention several occurrences of laterite, basalt and tuffs that occur in the plains to the north and west of the Inlet area. Five of these, occurring in allotments 9, parish of Kirrak (M. Ruttle); 31, Kirrak (W. Watson); 30A, parish of Kongwak (A. Blew); 37, Kongwak (J. McDowell); 38, Kongwak (R. W. McDowell) consist of laterite and tuffs with lapilli. Three others, occurring in allotments 23C, Kongwak (E. O'Connell); 41A, Kongwak (Beard); 97, parish of Leongatha (L. Follgrabe) and 25, Leongatha (D. Millar), consist of laterite, tuffs with lapilli, and basalt. One of basalt only, but occupying an area of only a few square yards, occurs in allotment 55A, Drumdlemara (M. Crowley). There are several other places on the plains nearer Leongatha, where volcanic rocks occur, but these I have not examined, so cannot discuss them. One notable example, however, near Cape Paterson, exposed on the beach at low tide, may be mentioned.

It is more of the character of the necks in the hill area, and consists largely of basalt, with no tuffs. Mr. Ferguson, who has examined it carefully, tells me that he regards some of the material as an agglomerate, so perhaps it may be included among the series characteristic of the plains area. These will be dealt with in the official reports of the surveys of the areas, so no further description of them will be given here, save to mention that Watson's tuff occurrence has the character of a fissure neck. It is a long, narrow strip of laterite and lapillaceous tuff, traceable almost continuously for a length of nearly 40 chains, with an average width of about 2½ chains.

All of these are probably volcanic necks, and not remnants of extensive beds of tuff and flows of basalt. There are, probably, numerous other occurrences of tuffs and basalt distributed over the plains, but hidden from sight by the thin covering of sediments present.

## Age of the Volcanic Necks.

Speaking in general terms, the age of the volcanic activity, of which the necks furnish evidence, can be set down with some degree of certainty. That it is post-Jurassic, of course, admits of no question. There seems almost conclusive correlative evidence that it was contemporaneous with the "Older Basalt" of the Mornington Peninsula and Western Port region. There, in sea cliffs along Western Port, the Cape Schanck coast, and at San Remo, basalt and associated tuffs can be clearly seen.

Resting on this basalt at Flinders is a small isolated patch of Bryozoan limestone[1] of Eocene age, so clearly the basalt there belongs to the Eocene or pre-Eocene period.

In various localities, such as at Berwick, Bacchus Marsh, Dargo High Plains, etc., leaf-bearing clays of probably Eocene age, underlie these basalts. There seems, therefore, no strong reason to doubt that the necks belong to the Eocene period.

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1 Pritchard, G. B.: The Geology of Flinders, "The Victorian Naturalist," February, 1903; Kitson, A. E.: Report on the Bryozoan Limestone at Flinders, "Records Geol. Sur. Vic.," vol. i., part i., 1902.

### Difference between Structure of the Volcanic Necks.

The cause of the difference in structure between the necks in the Jumbunna hill country, and those in the Anderson's Inlet and Powlett Plains series is, apparently, due to a difference in altitude. Those in the former district, which, without observed exception, are composed of basalt, and have no agglomerate or tuff, represent probably the lower portions of volcanic necks; while those of the plains series consisting of tuffs only, or of tuffs and agglomerate, or of tuffs, agglomerate and basalt, are probably the higher portions of similar contemporaneous necks. Ages of denudation have in the former case worn away the upper portions of the necks in the Jumbunna series, together with the contiguous Jurassic strata, and all of the younger sediments, if any, which overlay them. In the latter case, owing, probably, to protective covering and lower altitude, this upper portion of the necks has been preserved, and is only now undergoing denudation.

The conclusion is then forced upon one that the plains series were at one time at a greater altitude than the former. What then accounts for the reverse difference in present altitude? Faulting seems to be the cause, and faulting on a large scale. In dealing with an area such as this of the plains, covered as it is with a thin series of clays, sands, gravels and pebbly drift, and devoid of natural or artificial sections, it is impossible to obtain anything that serves as a definite stratigraphical guide or datum; and in the absence of the occurrence of similar deposits in the Jumbunna hill country one has to turn to the Jurassics themselves in the hope of finding evidence to assist in arriving at a conclusion.

A careful examination of every channel along the western and northern side of the Powlett Valley to the junction of Lance Creek with the Powlett has proved that in almost the whole of the cases in which dips have been obtainable, or the strata observable, they have shown an abnormally high angle of dip for Jurassic strata. The strata themselves have in several places been greatly compressed, crushed and tilted, and are so extremely like the highly-inclined strata of Silurian areas, both in structure and composition, as at first sight to raise doubts of their belonging to the Jurassic system. Dips of over 70 deg. are frequent, and in some cases the beds are almost vertical. The line of these dips follows very closely the present escarpment of the Powlett Valley, and it is interesting to note that on receding into the hills the dips rapidly become less, and in a few chains become normal. The same may be said of such of the dips as have been obtained further out on the flats. This seems to point conclusively towards a great earth movement or movements, and a general dislocation of the area to the south.

Additional evidence will probably be obtained in the Ruby district tending to further support the theory of great faulting of this region, but as, up to the present, nothing really definite has been obtained by me, that matter will not be further discussed in this paper. In the district to the north-east, Mr. Jas. H. Wright[1] has proved faulting to a great extent.

## Faults associated with Volcanic Necks.

The question of faults associated with the intense volcanic action of the time when these necks were formed is one of importance. Unfortunately, owing to the very limited area which is occupied by rocks bared sufficiently to admit of the examination of their physical characters, there are no data on which to found any definite conclusions as to the influence of the volcanic intrusions upon the invaded strata. The limited area around Neck 1 is the only one where there is any opportunity of determining faults. Even there the rock masses, which are chiefly thick-bedded sandstones with no distinguishing features, and the overlying mud and sea-weed preclude definite evidence from being obtained, except in the case of two or three most pronounced ones. Near the foot of the cliffs, however, at Townsend Bluff there are two or three beds of carbonaceous shale, impure coal, and bluish-grey mudstones. These afford some assistance in reading the nature of the faults.

There appears to be sufficient to regard the existence of three series of faults, two directly connected with the intrusion of the neck, and the third possibly so. The first two series may be divided into those having a general westerly bearing; and those

1 Note on the Geological Features of an Area in South Gippsland. Prog. Rep. Geol. Sur. Vic., No. viii.

having a general north-westerly one. Two examples of each can be seen branching away from the periphery of the neck, but their mutual relations cannot be determined.

The third, represented by a well-pronounced fault, not visibly connected with the neck, has an almost east and west bearing, and has caused a visible dislocation of the strata, but to what extent could not be ascertained.

As far as can be gathered from the evidence of the first two series of faults there has been a general throw of from a few inches to a few feet to the west. This seems to indicate that the intrusion of the volcanic mass has caused a westward push on that side of the neck, dislocating the strata, and setting up simultaneous or subsequent formation of the larger faults of both series. The smaller ones were probably caused by the settling of the masses after their initial and greater movement.

On the eastern side of the neck there are three distinct and sharply-defined extensions of the volcanic material forming steps, as it were, in the margin of the neck. They probably indicate the points of origin of faults having a general easterly bearing, and similar in character to those in the west. That they do represent faults, however, is not evident, since the strata here—massive, jointed sandstones—quite prevent definite evidence being obtained.

With the exception perhaps of a marginal displacement of 2 or 3 inches at the most, and confined to the periphery or thereabouts, that is dying out in the neck itself, there does not appear to have been any displacement of the volcanic material after its injection and solidification. All the definite larger faults, with the one exception, have apparently radiated from a common centre, that of the neck itself, and are directly attributable to volcanic agency.

Continuing the examination of the beach eastward from Neck 1, it is seen that there is a series of almost parallel breaks in the sandstones. These are now marked by narrow channels or rifts, varying in breadth from 2 or 3 inches to 6 feet. They may represent lines of fault, or perhaps only lines of jointing, eroded by sea action. In two cases, however, there is evidence of definite faulting, one of them having a throw of 6 feet, and N.W. bearing. Little beyond the general bearing of the faults can be obtained as, owing to surface material, the identification of any particular bed is a matter of doubt and difficulty.

The beach outcrops show the Jurassic strata here to form part of a dome of which the north-western, northern, and north-eastern portions are revealed by the dips near Neck 1, and the south-eastern portion by the dip east of the jetty.

The southern and south-western portion is of course hidden under the sands of the Inlet. The necks have thus been formed in an original dome of the Jurassics, or perhaps the dome has been caused by the raising of the strata due to volcanic action prior to the outburst of the neck.

### Polished Pebbles in the adjacent Jurassic Strata.

As bearing directly upon the occurrence of pebbles in the necks a few special remarks must be made upon the presence of pebbles in the Jurassic sandstones among which these necks occur, or in the locality at and near Savage's Hill.

Lying on the surface, or in water channels, or exposed in natural section in cliffs, pebbles of similar rocks to those described from Necks 2, 3 and 4 are by no means uncommon. I have found numbers of them myself close to the eastern and western margins of Neck 4, and have also received a small collection from Masters John and Tom Cuttriss. These pebbles have such an exceedingly high polish as to attract attention immediately when seen. Here, as in the necks, they occur both as entire pebbles, and as fragments. Frequently they have been broken across their greater lengths, or have flakes and chips missing from their sides. This has been caused by perfectly natural means, and is not due to chipping by aboriginals, as pebbles are being found in channels, which are at present deepening through decomposing rock *in situ*, and under conditions which preclude their transport from younger deposits. They are also found in the decomposing rock in road cuttings and other excavations.

These pebbles are most interesting, both on account of their origin, the agencies responsible for their excellent polish, and their transport to the localities where found. They comprise felsites, mica schists, jaspers, agates, chalcedony, carnelians, cherts, quartzites, quartz, lydianite, altered sandstones, and silicified wood. Most of these rocks are quite foreign to the district as far as known. Mr. Jas. Stirling records[1] a small outcrop of felsitic rocks at Waratah Bay, but no mica schists, cherts and jaspers have been recorded *in situ* within at least 30 miles of the spot. Though inliers of Silurian, such as those of Kongwak and the Powlett, do occur, there are no discovered remnants of older or more altered rock masses within it such as would furnish pebbles of the characters of some of those found. The evidence, therefore, is in favour of a comparatively distant origin for portion at least of the pebbles.

The polishing is not due to running water. Of this there can be no doubt. The only action to which it appears attributable is that of wind-blown sand, or wind-blown frozen snow.

The agency by which they were transported to their present position cannot have been the same as that which brought the finer sediments. Both on account of their size and the character of the rock they are composed of, this is quite impossible. The medium that conveyed or removed the material, chiefly felspathic quartz sand, from its source in a plutonic (probably a granite) area could not have brought down the heavy pebbles such as are found. The nature of the pebbles, also, suggests their derivation from a metamorphic area, which, if not more remote than that from which the sediments were derived, was, perhaps, quite a distinct one. Two means of transport suggest themselves: 1. That by driftwood; 2. That by floating ice.

## Land Surface during the Jurassic Period.

Before briefly discussing these probable agencies, a few remarks may be made on the probable nature of the land surface bordering part of the basin in which the Jurassic sediments were deposited.

It seems probable that the pebbles were originally of glacial origin, and were derived indirectly from the disintegration of pre-existing glacial deposits on the margin of the Jurassic basin.

The occurrence of glacial deposits in north central and north eastern Victoria, as at Carisbrook, Wild Duck Creek near Heath-

1 Notes on the Silver Deposits and Limestone Beds of Waratah Bay. Prog. Rep. Geol. Sur. Vic., No. viii.

cote, Pelluebla, Glenrowan, King Valley, Springhurst, Tarrawingee and Wooragee, and in south central Victoria, as at Bacchus Marsh, and under the deep leads at Pitfield, prove that they were originally very extensive. The period to which they belong being now generally recognised as Permo-Carboniferous or Carboniferous makes it highly probable that during the Jurassic period much larger areas were covered by them than is now the case. Consequently the derivation of these peculiar pebbles from such deposits seems probable.

In general character and nature of rock the pebbles in the Jurassics have such a striking resemblance to those in the glacial deposits as to force the conviction that they have either come from the same or similar rock masses, from which the latter were derived, or that the glacials have indirectly furnished them.

### Driftwood Theory.

Since most of the carbonaceous material and silicified trees and blocks of wood present in the Jurassic strata show distinct evidence of transport, and not growth *in situ*, it follows that this material must have been drifted. Whatever may have been the means by which the silicified wood—assuming it to belong to a period anterior to the Jurassic—was conveyed thither, the blocks and masses of carbonaceous material were probably brought by rivers into the Jurassic lake, on the surface of which they floated far and wide till, becoming waterlogged, they sank to the bottom. These masses of driftwood probably had entangled among them pebbles of various kinds, and thus may have been the means by which some at least of the pebbles were distributed among the Jurassic sediments.

### Surface and Ground Ice Theory.

The Jurassic deposits, as far as yet known, appear to be wholly of freshwater origin, judging by the fossils hitherto recorded. The fauna is represented by three species of freshwater mussel *(Unio)*; while the flora comprises several genera and species of ferns, and representatives of cycadaceous and coniferous vegetation. The deposits were, therefore, probably formed in a large lake basin, or several smaller ones. This lake may have been bounded in part by steep cliffs composed of Carboniferous glacial beds, and the climate may have been a rigorous one in winter. By assuming the operation of blown sand under strong winds the conditions would be present for the polishing of any pebbles disintegrated from the subjacent glacial beds. Continued action of blown sand on these pebbles would soon result in them acquiring their high polish. Now, if singly, or in numbers, they fell over the cliffs during the winter, on to the frozen surface of the lake, nothing remained but the floating away of the burdened ice when the thaw set in, and the subsequent dispersion of the transported pebbles among the sand of the lake bed as the ice of the floes melted away; or again, the pebbles may have fallen over the cliffs into shallow water, been frozen into ground ice, subsequently floated off, and finally dropped when the ice melted. These polished pebbles are found in many parts of the Jurassic system of South Gippsland. Few, however, have such a high polish as have those at Anderson's Inlet. This fact admits of the readier acceptance of the theory, since, assuming ground ice to have been the means of transport, the whole of the pebbles could hardly have been floated away quickly enough after their fall into the waters of the lake to have prevented their polish from being destroyed, either partially or wholly, by abrasion among the shingle and pebbles of the shore.

The absence of angular pieces of rock from among these polished pebbles can be explained by the reasonable assumption that the cliffs were composed wholly of glacial deposits, and as such they would contain comparatively few small angular pieces.

Again, the ice transport theory would probably explain the fracturing of the pebbles since they would thus have been subjected to great variations of temperature. The occurrence of so many of these fractured pebbles among the Jurassic sediments, as well as in the volcanic necks, is a striking feature. Had they been confined to the necks their fracturing could easily have been accounted for by violent contact with the material in the old volcanoes.

A consideration of these matters makes it seem not improbable that both of these agencies—driftwood and floating ice—have operated in the transport of these included pebbles in the Jurassics. It seems, besides, by no means improbable, that contemporaneous glacial action may account for some of the features noticeable among the sediments of this system. Not the least striking is the peculiar bluish and olive colour of the great majority of the mudstones. These have an exceedingly strong resemblance to the clay of the typical glacial deposits of Bacchus Marsh, Victoria, and Wynyard, Tasmania. The derivation of their mud from glacial streams discharging into the Jurassic lake is, therefore, not improbable.

## Origin of Included Pebbles in Volcanic Necks.

The origin of the included pebbles in the necks is of interest. Two probable sources may be suggested :—

1. From among the Jurassic sediments, dispersed principally through the sandstones.

2. From a bed of conglomerate in the Jurassic system, or in some system underlying this one.

In view of the occurrence of the solitary pebbles among the local Jurassic strata, the former origin seems the more probable.

With reference to the latter it may be stated that nowhere in the visible Jurassic strata of the district is there any bed of conglomerate having polished pebbles; neither is there, with the exception of the conglomerates at San Remo, which occur at sea level, and may perhaps be the basal beds of the series, any deposit extensive enough to be called a bed of conglomerate. Besides, these San Remo conglomerates are composed of rocks entirely different from those under consideration, and the pebbles are not polished. The probability of the derivation of these pebbles, therefore, from a Jurassic bed of conglomerate is remote.

Then, as regards their possible derivation from a subjacent conglomerate of pre-Jurassic age, there does not appear to be any evidence in support. On the other hand, the absence of fragments of unpolished rocks, except those of Jurassic strata, practically prove that such was not their origin, since it is hardly likely that fragments of the rocks of other beds of the series would not have been included among the volcanic material had the pebbles been derived from such a source.

The pebbles in the necks have the same general shape as those among the Jurassics, and are broken in a similar way. They have in several cases even the characteristic polish, though it is not so high as that of those in the Jurassics, and also the peculiar and numerous small semi-circular and circular fractures without separation, so common among some of these pebbles, and also of those among the glacial deposits of Victoria. One may be specially mentioned as it is of silicified wood, similar to that from the sediments, and possesses a considerable polish. It is, therefore, of particular interest, and assists materially in supporting the opinion held.

It is but to be expected that polished stones subjected to the treatment meted out to the constituents of agglomerates and tuffs would soon lose their polish through the attrition caused by the volcanic and other material. There is, however, one difficulty in the way of unreservedly accepting this mode of origin. This is the fact that the visible ash contains comparatively little fine quartz sand, such as would be expected to be found in it, were similar sandstones to those forming Jurassic sediments absorbed by a volcano, subsequently pulverised and mixed up, and finally allowed to settle. It is perhaps probable, however, that the bulk of the visible material derived from the Jurassics may have been obtained from the mudstone beds of the system.

## General Remarks.

As far as I am aware, these Anderson's Inlet necks are the first of their kind, *i.e.*, those composed of clastic volcanic materials, to be described in Victoria. Messrs. T. S. Hall, M.A., and G. B. Pritchard, have described[1] certain clastic volcanic rocks at Curlewis, near Geelong, as a spot close to a vent of the Older Volcanoes, while Mr. Hall has further recorded[2] two volcanic necks of basalt at Mount Consultation and Diamond Hill, Castlemaine.

In New South Wales, in the neighbourhood of Sydney, at the prismatic sandstone quarry in the cliffs at Bondi, there is an occurrence of volcanic material, which has been briefly described[3] by Professor David, B.A., F.R.S.

1 Notes on the Eocene Strata of the Bellarine Peninsula, with brief reference to other deposits. Proc. Roy. Soc. Vic., vol. vi. (n.s.), 1894, p. 3.

2 The Geology of Castlemaine, with a sub-division of the Lower Silurian Rocks of Victoria, and a list of Minerals. Proc. Roy. Soc. Vic., vol. vii. (N.S.), 1895, p. 81.

3 Notes on Some Points of Basalt Eruption in New South Wales. Trans. Geol. Soc. Aust., vol. i., pt. 1, p. 25. Melbourne, 1886.

Several much finer examples of necks have since been discovered in the neighbourhood of Sydney. References to occurrences in New South Wales are appended.[1]

The accompanying geological map of portion of South Gippsland is based upon the new Geological Map of Victoria. Such additional information as has been obtained since the completion of that map, has been added in a general way. The whole of the Waratah Bay area has been retained as Silurian, since undoubted Silurian limestones occur there. Mr. Stirling speaks[2] of some of the rocks in it as pre-Silurian and Cambrian, while Professor Gregory, D.Sc., F.R.S., Director of the Geological Survey of Victoria, has suggested[3] the probability of the occurrence there of an outcrop of pre-Ordovician rocks.

The period to which the granite of Yanakie, Wilson's Promontory, and Cape Woolamai belongs has not yet been definitely ascertained, though generally regarded as Devonian.

The geological map of the locality at Townsend Bluff, Anderson's Inlet, has been prepared from field notes obtained by a careful survey made with a prismatic compass and by pacing. The heights are aneroid measurements. The two sections across the necks are added to simply illustrate their character.

I am much indebted to Mr. E. F. Pittman, A.R.S.M., Government Geologist of New South Wales, for references to the Volcanic Necks literature, to Mr. A. Cuttriss and his two sons for the kindly help they have given me in various ways while the examination of the locality was being carried out, and to Mr. A. Elms, who accompanied and assisted me during one of my visits there.

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1 David, Professor T. W. E., Smeeth, W. F., Watt, J. A.: Preliminary Note on the Occurrence of a Chromite-bearing Rock in the Basalt at the Pennant Hills Quarry, near Parramatta. Jour. Roy. Soc. N.S.W., vol. xxvii., 1893.

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2 *Op. cit.*

3 The Heathcotian, a pre-Ordovician Series—and its distribution in Victoria. Proc. Roy. Soc. Vic., vol. xv. (n.s.), pt. ii., 1903, pp. 167, 173.